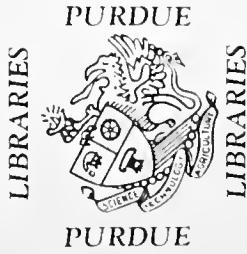
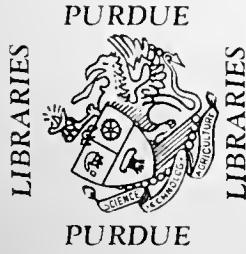
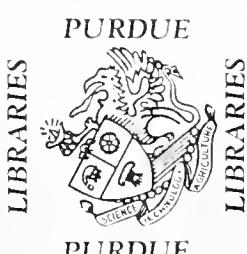
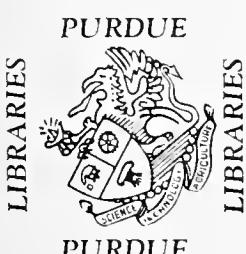
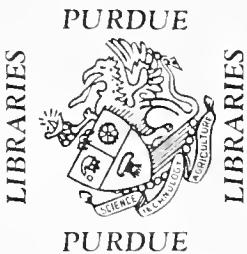
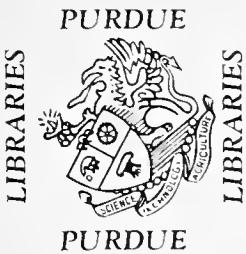


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ROLE OF RESEARCH IN SOLVING
HIGHWAY AND URBAN PROBLEMS

APRIL 1960

NO. 7

1-13

Joint
Highway
Research
Project

by

K.B. WOODS

PURDUE UNIVERSITY
LAFAYETTE INDIANA



Final Report

AIRPHOTO INTERPRETATION OF ENGINEERING SOILS OF
Kosciusko County, Indiana

TO: K. B. Woods, Director
Joint Highway Research Project

FROM: H. L. Michael, Assistant Director
Joint Highway Research Project

DATE: March 3, 1960
FILE: 1-4-60-22
Project No.: 0-36-513

The attached report entitled "Aerophore Mercury Addition to the Molding Soils of Kosciusko County, Indiana," completes a portion of the project concerned with Molding Soil: the wire, iron and the clay soil. The report was prepared by F. T. Tidwell, Research Engineer of the U.S. Forest Service, former research assistant, Joint Highway Research Project.

The soils mapping of Kosciusko County was done primarily by soil photo interpretation. However, the soil profiles are classified by field investigation. To increase the value of the county soil maps, 100 soil types were sampled and tests were performed on the soil taken from each. The soil testing data included grain size analysis, plastic limit, liquid limit, optimum moisture content for cohesion, dry weight, dry unit weight, proctor test and CEC. The soils were classified using the Soil Survey Classification System and the Bureau of the Geological Survey.

An ozalid print of the engineering office map will be furnished to the appropriate classification listed in a table on page 10. These are included in the back of the reports.

Respectful communication

J. L. Michael
1. L. Michael, Esq., M.A.

HLM: ci

Attachment

cc: F. L. Ashbaucher	J. D. Miles
J. R. Cooper	J. D. Mills
W. L. Dolch	J. E. Vogelgesang
W. H. Goetz	J. L. Waling
F. F. Havey	J. E. Wilson
G. A. Leonards	J. J. Yoder
J. F. McLaughlin	J. A. Hawkins (M. B. Scott)

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at large.

University. Finally, the picture would be warped indeed without acknowledgment of the truly great research contributions of the Bureau of Public Roads, the highway industry itself, plus contributions from foreign sources, as for instance, the British Road Research Laboratories.

Early Research Contributions

In 1929 this author (1) raised the question as to whether or not the Civil Engineers of this country could have handled a highway of this magnitude, the current one, 30 or 40 years ago. A quick survey of the history of the period 1920 and 1930 will show without particular difficulty that the answer is "Yes," by adding the to cope with modern highway problems. This, in fact, is true, the collective research contributions of Highway Departments, State, county, and Federal Government, materials producers, aided by the great efforts of the Highway Research Board, American Association of State Highways, and the American Society of Testing Materials, have made our highway industry, in my judgment, to execute their present responsibilities in an excellent manner. In general to meet the demands of this time, during 1930, 1931, and 1932, the credit of the Bureau of Public Roads and the Congress of the United States to pursue basic programs of research have been extended. The results of these findings which can be used to guide the financing, planning, design, construction, and operation of these modern highways.

In considering the present state of the art of highway research 10 years ago it is surprising to note an extract of a section written by L. L. Bates in service—with a considerable mileage still, today, used as basis for modern pavements. Some concepts of basic design were developed and are being put to through controlled test sections and test roads designed specifically for this purpose. Examples of such projects are the field experiments conducted by the Bureau of Public Roads at Arlington, Virginia (3), and Connecticut Avenue, Washington, D. C. (4). At the same time the results from the "Bates Test Road" (5)

established a pattern of design which lasted until about 1945. During and after the second World War, pavements constructed under these design concepts failed badly, especially in sections of the country where clay-like soils predominated and under conditions of high volume of heavy loads (37). This was due to a wrong design approach and thus indicated (30, 34). Test roads 15, 16, and 17, built by the Highway Research Board under the asphalt road project I, were in eastern Maryland (3). The concern focused on the State Highway of Maryland specifically, so-called "the 1910 road test" (3, 6). The 23-million-dollar Maryland Bond was conceived to build roads in Maryland, but is still under construction.

During this 40-year period of test roads, a wide variety of highway design was performed in the laboratories of the Bureau of Public Roads, universities, State Highway's and state transportation departments, and others. The highway "ideal" "ideal" "ideal" road test of 1910, in particular at this time, was the following: the well-known "Highway Research Board" was organized in 1923 under the U.S. Office of the National Research Council (35) and for the National Academy of Sciences (36). The American Association of State Highway Officials was organized in 1914, and its first major document was a report (37, 38, 39). The "ideal" road test was performed in Missouri, with the first two reports in 1914 (37, 38) and 1915 (39, 40, 41), and "Interim Report" in 1916 (37). Attention was given to the "ideal" road test on city streets long before the turn of the century and by 1910 considerable literature was available (42, 43), Ladd (20, 21) had laid down the principles of the "ideal" surface and the subsequent design of pavements, and continued to do so in great detail (22, 23, 24). Such names as Rose (25), Reid (26), and especially Burton and Bankman (27). Soya (29), and Terzaghi (30, 31, 32) began to appear in the literature during this period because of increased interest in the heavy subgrades. The classical work on the gradation of aggregates and the development of the well-known "Fuller's Curve" was published in 1907 (33) and 1911. After the efforts placed on highway construction, research program was organized in 1933 in **fields of materials research. Committee D-4 on road and paving materials of**

the ASTM was organized in 1904, primarily to develop methods of tests and specifications for pavements including wood blocks, granite blocks, brick, and bituminous mixtures. Committee C-5 on Concrete and Concrete Aggregates was formed in 1924 under the leadership of Stanford E. Thompson (33) but Committee D-10 on Soils for Engineering Purposes was not organized until 1936.

Soon after 1920 interest was evidenced in some of the broad aspects of highway engineering including finance (14), construction (34, 36, 37), traffic control (33, 39, 40, 41, 42, 43, 44), and the relationship of highways to other transportation, portation (13, 39, 45). The current great interest in continuing education on these and many other items of highway engineering is indicated by the more than 1,000,000 highway people who registered at the January, 1960, annual meeting of the Highway Research Board in Washington, D. C.

the Bureau of Tests in the general field of highway and mechanics (54). This included in this report was one of the early sets of typical embankment control curves averaged from 461 Ohio soil samples tested in 1936. This work has been continued and in 1958, Joslin (55) presented curves averaged from 10,000 samples. The curves are widely used on various types of earthwork brought in the country.

Other examples of cooperative work between the University and the Highway Department can be cited--however, three recent outcomes may suffice to illustrate a long-term spirit of interest on the part of both organizations in highway and highway research. This has long been well-exemplified by Dr. C. L. Joslin and other members of the staff of the Bureau of Tests and by many others in the control office, and by members of the university staff in consulting, in meetings of such well-known organizations as the Highway Research Board, the National Research Council, the Mexican Society of Civil Engineers, The Canadian Society for Testing Materials, and American Association of State Highway and American Concrete Institute, Association of Asphalt Pavement Lined, and others.

Significant to the above mentioned cooperative programs is the fact that all three involved highway soil mechanics. Consider for a moment the potential of the entire spectrum of highway engineering is opened for joint research effort. Highway engineering, in the broad sense, stretches beyond the scope of a single engineering discipline, touching as it does on finance, mineral industry, traffic, economics, engineering law and even the more "soft" of construction law. These disciplines are in addition to the conventional Civil engineering disciplines such as Structural Engineering, Soil mechanics and Foundations, Materials, Construction, Traffic engineering, and operations. The great schools and universities of this country and Canada are equipped, and are interested in broad service to the separate highway departments.

Cooperative Highway Research Programs

With the great scope of unsolved problems encountered in the highway field, it is only natural that the practicing highway engineer in the Federal, State, and local governments and the professional staffs of the institutions of higher learning would become interested in joint research efforts. This joint effort may have been developed in the separate states of the United States and in some of the provinces of Canada. As a general rule, the cooperative efforts between Highway Departments and universities--and frequently with Public Roads as an important third party--have two main objectives, namely: (a) the solution of problems confronting the highway agency by the application of research methods, which may be immediate or long range problems; both basic and applied research can be found a place; (b) the maximum effort of arousing young engineers to pursue graduate programs in Civil Engineering so that they may be able to continue through their own research and through teaching in universities or in the staffs of Federal, State, local government agencies, or the highway industry if desired. It is important to note here that the highway industry has its share of considerable responsibility in contributing to research and development and to the fellowship programs of our colleges and universities dedicated to graduate work.

Many of the cooperative programs have been very successful. Iowa, the University of the University of Illinois have had long-term formal arrangements with the Iowa and Illinois Highway Departments respectively, and the Bureau of Public Roads' private practice projects have been similar. In the more recent years, more formal arrangements have been indicated in both countries.

Both formal and informal arrangements between the Highway Department and a college or university are common in the United States and Canada--and interest in developing cooperative highway research programs, with public roads as one of the sponsors is increasing rapidly. Among the states with informal arrangements can be listed Florida, Kansas, Maine, Minnesota, and Texas. Various types of

Conclusions and Outlook for Future Work: The following conclusions are drawn:
In each state of the system, the probability of being in a particular state is given by the
seeds, $\{f_{i,j}\}_{i,j}$, in the i th row of the $\{f_{i,j}\}_{i,j}$ matrix. The probability of being in a
certain state of the system is given by the i th row of the $\{f_{i,j}\}_{i,j}$ matrix.

Important research topics for the future work are:

1. The effect of the initial state on the final state of the system.



Indiana's JHRR

One of the early cooperative highway research undertakings was the Indiana Highway Research Project started informally at Purdue University in 1936 (3). The organization was established as a result of an agreement between the Chairman of the State Highway Commission of Indiana and the head of the College of Engineering at Purdue University. During the first year the Commission paid \$25,000 for research and on March 11, 1937, the organization was established by an act of the State Legislature which permitted the Commission to allocate \$50,000 annually for the operation of the research organization. In 1941 the Legislature revised the 1937 act, to make the permissive power the Highway Department may allocate to the University. The offices and Director are located in the Civil Engineering Building at Purdue University.

Close contact is maintained with the Highway Department through an Advisory Board. The Board outlines policy, receives and recommends projects, receives reports on projects, approves release of research data, and recommends to the Highway Department of the University the projects which are to be allocated. In close contact with the program of research, the Highway Department makes an effort to guide the research endeavors toward the most pressing Indiana highway problems to apply quickly the knowledge gained. In turn, the University board of trustees are better able to point the University resources toward the development of the research projects designed to solve some of the highway problems in Indiana.

The Highway Research Project is a unit in the Civil Engineering Department and is administered by the head of the School of Civil Engineering, who is appointed as Director. At the present time there are nine research divisions, as follows: Soils, Concrete and Rigid Pavements, Bituminous Materials and Flexible Pavements, Airphoto Interpretation, Chemical, Traffic, Economics and Administration, Structures, and Hydraulics. These divisions are the scene of regular work and the



area of research programs, and most of them are the sources of educational courses at the graduate and undergraduate level. At the present time, the staff in the Project includes 24 full-time employees and 15 half-time graduate research assistants. From 50 to 75 undergraduates are employed on a part-time basis to assist on research projects. In addition to the main bodies of research work produced by the staff in the 4-year period of the project's existence, 100 annual progress reports have been written from time to time (57, 58, 59).

Some Projects of the GTRC

In presenting a few highlights covering the 20 years of the GTRC, the Research Projects, the research projects are divided into those of general interest of State and local interests, and those of State and National interest.

Soil Mechanics and Pavements. As a technical area of investigation, work in the field of distribution and engineering characteristics of soils is not especially true in the Midwest where strong research and teaching programs have been developed at Purdue University and have at various times, for instance, the use of Highway pavement or foundation soils, strongly that one of the major contributions to their program has been the work on Indiana Grits (61) published in 1931. A generalized on Indiana soils is of interest in that, in this and later in the Soil Survey publications, the detailed work done in this field of soil research has continued for the past 17 years in refining engineering soil boundaries in various studies of Indiana (61). There is good reason to believe that this work will continue to be conducted well into the future in the course of a new Indiana project which will probably be organized shortly. The joint GTRC research project with the Indiana Agricultural Experiment Station, the Soil Conservation Service, and the Bureau of Public Roads, the kind of soil research is almost ideal for the state of Indiana. While diversified, these research programs can be greatly enlarged within the field of pavements. A good example of the work done in this field is the study of the engineering properties of the soils of the Midwest in the construction of various materials of construction.

At Purdue, interest has continued for 20 years or so in connection with the fundamental properties of soils, such as frost action (62, 63), soil stability (64) (65, 66, 67), base courses for rigid and flexible pavements (68), the pumping of pavements (69, 70), and soil explorations for highway projects (71, 72, 73, 74, 75). Included among some unusual soil studies is the work of Goldsmith et al (76), on deflection measurements made from deep-seated bench marks (76).

and the very interesting work of Bull and Belote (1971) on the use of reduced protection for highway subgrade soils.

The Joint Highway Research Project also operates a data and photo interpretation and photogrammetric research laboratory. This unit is used to refine the art of airphoto interpretation and the science of photogrammetry as applied to the location and planning of water works and highway systems. The laboratory is primarily concerned with the development of the use of aerial strip photography, acute watershed characteristics, engineering concepts, location of pipelines and borrow materials, and special applications of highway projects.

The State of Indiana has "improving major roads" and the Indiana State 1:24,000 topographic maps serve as the basic starting point for mapping. In individual counties it is anticipated in the mid-1960's that the aerial photographs will be used to delineate stream and gully drainage channels. 117 of 92 counties have been completely mapped as a County drainage network in a chain of 1 inch by 1/2 inch strips which are expanded. The older, smaller county data on the drainage network and watershed areas for planning purposes will be used.

The photogrammetric section develops special studies that cannot be scheduled in the Highway Department's Aeronautical Laboratory (3). At least 10 students have worked on such studies as the "Photogrammetric Treatment of the Pay-Plantations in Indiana," "Construction of a Master Project for the Control of Land-use Development of Indiana's Industrial Areas," "Aerial Survey of Indiana to Indiana to determine resources for highway planning" (4). Some interest has also been completed in the use of aerial strip photography for various highway and airport applications, including the nature of performance with respect to



Concrete and Concrete Aggregates. A second very practical area for cooperative research is in the field of materials of construction. Each of the geographical, geological, and major political units of the continent may have problems with materials, peculiar to the particular unit, and not necessarily in common with adjacent areas. Ohio may have problems in common with and surrounding states, i.e., Pennsylvania, West Virginia, Kentucky, Indiana, and Michigan. However, it is likewise true that all of the problems with native materials in Ohio are not in common with any of these sister states. It is more practical than to consider a state-wide, cooperative research program on the description and engineering characteristics of the materials commonly used in highway construction.

Again, again the highway research in Indiana as an example, large laboratory and field programs have been underway for about 20 years and the laboratory programs are being continued. One of the early contributions that made possible through detailed studies of the performance of concrete pavements, the research produced a clear correlation between the cause of coarse aggregate used in construction and the satisfactory or unsatisfactory performance of the pavements (134).

* This paper was chosen as the 1945 Highway Research Award.

Furthermore, it was observed that the susceptibility to blowouts was an indication of the use of poor-quality, non-scarable aggregates, which when used in pavements, resulted in short life-expectancy in areas of severe frost with subgrades of clay-like characteristics. This research was of great importance in developing specifications (84, 85) for portland cement concrete aggregates but it also had a significant influence on the design of rigid pavements in connection with the **abandonment** of the traditional use of expansion joints. This work led to many detailed laboratory studies of aggregate and of concrete. Chemical investigations were reported late (86, 87). Indiana limestone aggregates were further

studied in an effort to understand their performance in frost action. The study involved the porosity, permeability, and absorption properties of the materials, and good correlations were obtained between these properties and the durability characteristics. Some of this work was reported by Leeks, Dolch, and Woods (71) and more recently by Dolch (82). The gravel aggregates of Indiana have also received much research attention with special emphasis on short and other deleterious substances (90) together with corrosive materials which might be employed (91). Cracks in the structural concrete in the states (83) and fatigue of aircraft wings caused (92) have also received attention.

Pavement slipperiness and pavements durability design from this viewpoint are becoming very important as the volume and speed of traffic continues to increase. Materials from which pavements are made need to be re-evaluated from the standpoint of their resistance to the polishing action of traffic (93). The materials used in this problem are generally, in raw, unrefined stone, research is needed to assist the highway engineer in the use of materials and design of mixtures to provide the best answers to the problem. The Joint Highway Research Project has undertaken field studies to classify materials as to polish resistance (95). The size and shape problem has been investigated to provide the information necessary to utilize the use of the materials available. The most recent work on this problem concerns the use of available sand for producing mixtures for de-silicification, and a laboratory sand-size study has evaluated such factors as particle shape, clay content, and sand grading (96). The cooperative study has been carried to the field for the purpose of developing field data to corroborate laboratory results and thereby to establish specifications and design criteria (97).



Bituminous Materials Research. Bituminous materials and bituminous-aggregate mixtures are receiving increasingly greater attention in highway-research laboratories as a result of (a) continuous increases in the traffic volume and loads (b) increasing use of bituminous mixtures for flexible pavement construction or for resurfacing. Again, some of the research of the Joint Highway Research Project can be used to illustrate how a University-Highway Departmental cooperation program can function to provide research data for use in solving current highway problems. The basic, long-time program which has been underway, almost since the inception of the cooperative work at Purdue, is concerned with the fundamental characteristics of bituminous-aggregate mixtures as related to their ability to carry traffic loads. In Indiana, this involves a wide range of mixtures which are used under a variety of conditions of service, ranging from low-grade secondary surfaces to high-grade bituminous concrete. This kind of long-term program requires frequent observations of field performance and great effort on the part of the research team to develop correlations between performance and laboratory methods of test. Durability of mixtures is of course another major subject for research.

One of the outstanding contributions in this area of research has been the long-term study covering the evaluation of several laboratory tests prior to the design of the mixtures and performance of these mixtures under traffic. An early study of this kind covered evaluation of the Marshall stability test as a method of indicating strength values (93). A more recent study has come with an evaluation of the Hveem Stabilometer method as a strength test, particularly as applied to mixtures of the open type and as opposed to the dense mixtures to which the test is normally applied (99). In evaluating Marshall and Hveem methods, use was made of rational tests such as unconfined and triaxial strengths (93, 100). One of the most important aspects of mixture design for any construc-



tion agency is the evaluation of mixture variables as affected by the materials available for use. Many of the studies cited above bear on this problem (93, 99, 100). The evaluation of such factors as aggregate shape, both in the coarse and fine aggregate, is a case in point (101, 102). At Indiana there has been a continuing effort to understand better the effect of local variables, as determined by service conditions, on deformation characteristics of bituminous mixtures. Temperature, confining condition, rate of loading and repetition of load are the major factors studied (103, 104). The application of the concepts derived from such studies in order to give practical values to laboratory procedures requires close cooperation between the Laboratory and the field and a close university-Highway Department relationship. Mix design procedures have been adjusted to fit the conditions in Indiana (105) and performance data are obtained through test sections installed by the Highway Department and evaluated by Indiana personnel (106).

Another area to which the research organization has been able to make significant contributions concerns the durability characteristics of bituminous mixtures. The nature of this problem is such as to make evaluation difficult, but fundamental relationships have been brought out by laboratory studies (107). The application of the sonic test to the stripping resistance of bituminous mixtures, because it is a non-destructive type of test, has enabled further work to be made along the way to solving this problem (108).

Traffic Engineering and Highway Planning. In recent years Joint Highway Research Project efforts in the areas of traffic engineering and highway planning have been expanded and the outlook is for continued expansion, especially in urban planning and transportation economics. These contributions to the Indiana transportation system and specifically the State Highway Department of Indiana have been of major importance. Some of the studies which have proved particularly valuable are studies of highway impact, highway "needs," traffic accidents, the characteristics of traffic on Indiana highways, origin-destination surveys, the location of slippery road sections, roughness of highways, administration and organization of state and local highway departments, and county highway planning.

The initial studies of the impact of highway bypasses are well known and specifically in Indiana resulted in a broader and wiser application of the principle of controlled access (109, 110, 111). Impact studies are continuing and currently an attempt is being made to evaluate the influence on an urban area of a major highway improvement and the impact in rural and urban areas of a section of the Interstate System. The project staff with the assistance of personnel from the State Highway Department conducted a "needs" study of the highway system in Indiana, which contributed heavily to the passage by the State Legislature, and the almost universal acceptance, of legislation which in turn provided much-needed highway revenue (112, 113). Much information obtained in this study is currently being used in highway planning in Indiana and a sufficient copy of this study which was a part of the needs study provided the basis for the adoption by the State Highway Department of this priority tool.

In the area of traffic safety, recent research projects have explored relationships between elements of the roadway and accidents, and methods of analysis have been developed which provide for the determination of the causes of accidents at very high-accident locations (114). The application of the results

of this latter research resulted in the finding and the subsequent minimization of a major cause of accidents at 27 out of 36 high-accident locations. Research just completed in this area has also produced a technique of accident analysis which results in the efficient location of slippery sections of highway so that they can be "designed." The method now only locates slippery sections but also assigns a priority of remedial action which considers the alignment of the pavement and the volume of traffic on the highway. The technique of traffic selection of sites which correlates very well with the results of the survey by the vehicle stopping distance method, a technique which also was developed by research in the Joint Highway Research Project. Staff members have also cooperated with the Interborough Survey Unit of the State Highway Department and have advised on the performance of 2,200 urban bridges and de-bridges while at the same time using the data for research on methodology, materials, use of these structures. Road traffic studies have now been conducted for the past 20 years and these, along with a study of the volume characteristics of traffic have been of value to the Highway Planning Survey Unit of the State Highway Department. The Project also developed a roughometer for the State Highway Department and has delivered it to them for their regular and continuing use.

Local roads have also received attention in project research and development of practical methods of local road identification, classification, priority of use, etc. have been developed (113, 115). In order to give assistance to local authorities of cities and counties a Planning and Service Unit has been established to advise and study local problems (117). This Unit receives many requests for assistance from local authorities and through public relations and subsequent improvements in highway travel in these communities are obtained with a small expenditure of time and money.

Other Important Studies. The Project also cooperates with the Highway Planning Survey of the State Highway Department by conducting some research studies



which are partially financed with Highway Planning Survey funds. At the present time several such studies are in progress including research on the Hydraulics of Arch Bridges (118). The breadth of Indiana's highway research program is further reflected by the work done in economics (119), finance (120), structures (121), and design (122, 123, 124).



Urban Research

Highway transportation is deeply involved with all other methods of transportation and especially with the entire problem of urban development. Work in this area needs immediate attention and your author strongly recommends careful consideration toward the development of strong programs in both areas. Many highway departments are already interested and there is much interest on the part of the Bureau of Public Roads.

Lockbury in his excellent report presented at the January, 1960, meeting of the Highway Research Board (125) in his concept of a new pattern of urban development, states that "More than two-thirds of the national population increase is going into standard metropolitan areas outside of their central cities." He also concludes that "... shockingly little is being done to understand this major phenomenon of the times or to prepare adequately with its problems, or for taking the best of the opportunities it presents." Davis commented at the same meeting (126) that, "It seems obvious that research into the problems of the functioning of the urban system requires bringing into play the competencies of a number of disciplines...." In the transportation and related fields important areas of immediate attention. To name a few topics, consider some of the following:

1. The development of better standards and techniques for origin and destination surveys.
2. Obtaining and processing, including costs, finance, and use.
3. Inter-community travel.
4. Parking and storage terminals.
5. Expressways, bypasses, subways, and use of helicopters.
6. Inter-fringe travel, trip length, and limited access.
7. Problems in the field of political science, including city and town governments, zoning, inter-government relations, authorities and commissions, and inter-agency relationships.



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8. Legal and engineering problems such as land acquisition and control, use of eminent domain, building codes, government ownership, and control of traffic.
9. Economics - i.e., use of natural resources, residential-business-industrial patterns, land use, ownership of utilities, etc.
10. Public and private housing, and slum clearance.
11. Use of water for power, cooling, etc., flood control, sanitary engineering, and services and utilities, public health and hospitals.
12. Urban development in general.
13. Problems of finance such as taxes, rentals, housing, private, state and Federal grants, bond issues, etc.
14. Problems of fumes and noise.

In looking at this problem it should be noted that much research is being performed and that a great deal more is underway. Publications of research findings are widespread including suggested programs of research (1, 7, 11, 12, 130).

Conclusions

One of the best summaries this writer has seen of the value of highway research has been made by Davis (126) in his chairman's address at the annual meeting of the Highway Research Board. He summarized the recent proposal by Mr. E. H. Holmes of the Bureau of Public Roads as follows: "In the United States in 1955 involved in expenditure of some 45,000 million, which was only 10% of the direct expenditures for highways (including design, construction, maintenance, and administration) in that year of almost 10 billion dollars, the direct costs in research would thus appear to be only of the order of 2 million per calendar year. The expenditure on research is a relatively small proportion of total costs, but it could be of many industries to be an acceptably important in the estimation of future costs."

It has been a pleasure to have had this opportunity to have been a part of this meeting. I hope my brief remarks will encourage some of you to pursue programs of highway research.

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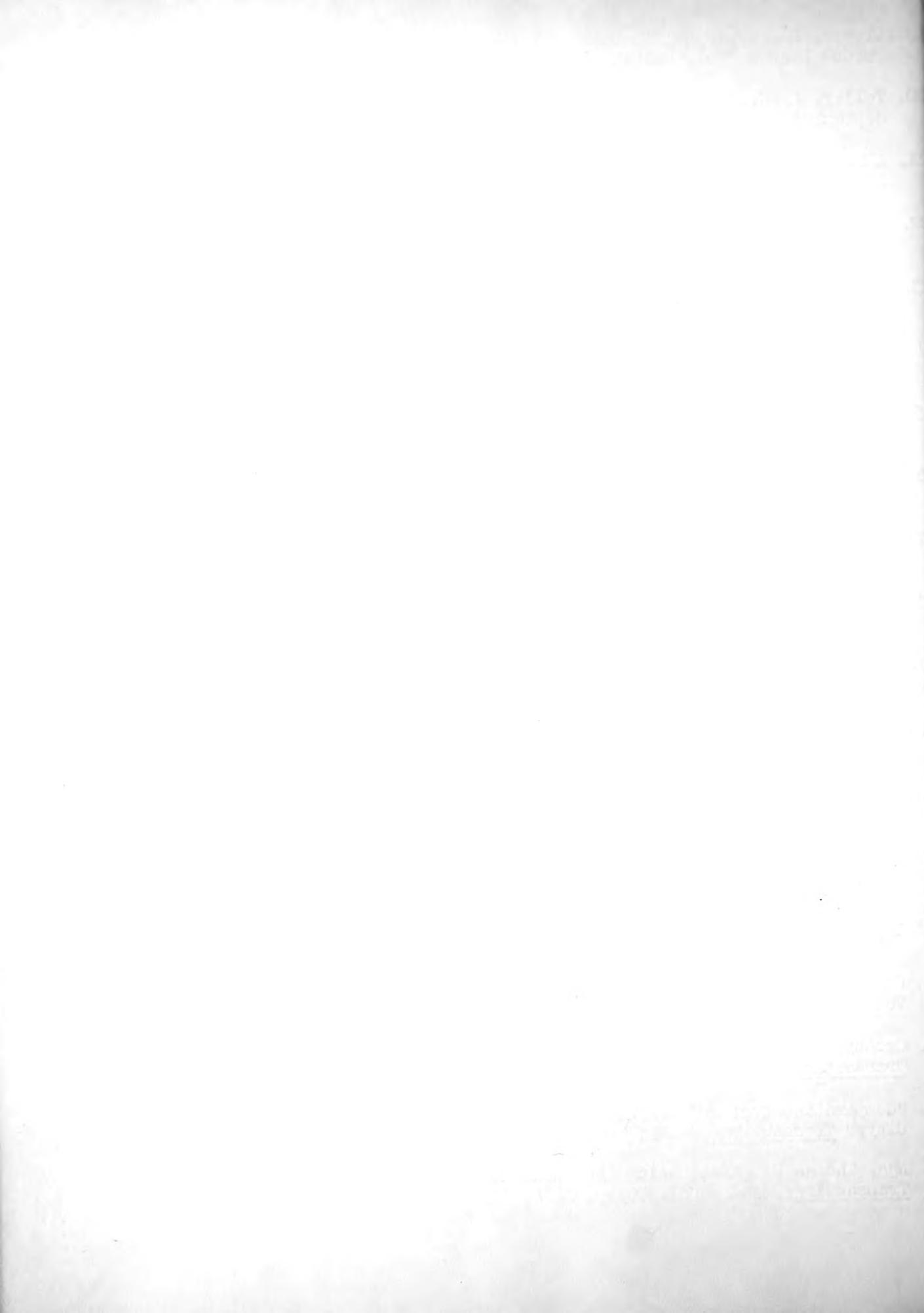
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